

DEPARTMENT OF ECONOMICS

WORKING PAPER SERIES

2011-03



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Organizational Capital and the International Co-movement of Investment

April 2011

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Abstract

A recent literature explores the macroeconomic implications of organizational capital (OC) and especially its ability to resolve discrepancies between existing models and data. This paper contributes to the OC literature by studying the effect of OC on international investment flows in the context of a two-country real business cycle model. The presence of OC introduces novel considerations into agents' investment decisions since current investment and future productivity levels are positively linked. These new considerations help bring the model closer to the data. In response to a productivity shock in one country, investment increases in both countries, producing positive international co-movement in investment, a feature of the data that several IRBC models fail to produce.

Keywords: International RBC, learning by doing, organizational capital, cross-country correlations, investment.

JEL classification: F41,F21,E32

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1. Introduction

While it is conventional to view the production technology available to firms as one which takes only two inputs, labor and physical capital, a number of economists have argued that a third input which incorporates production relevant knowledge is also very important. This input is often referred to as organizational capital. Organizational capital (OC) may be thought of in terms of knowledge or ideas related to the process of production that help determine how much output results from the application of conventional inputs in the context of a particular technology. We think of OC as being a key determinant of the endogenous component of productivity, something that is co-produced by firms in the process of creating output. The idea that firms are store-houses of OC can be found in Prescott and Vischer (1980) and more recently in Atkeson and Kehoe (2005) who measure the value of OC in the US economy and find that it is roughly half the size of the physical capital stock. The idea is also implicitly contained in the sizeable empirical industrial organization literature on estimating learning curves at the industry or firm level.

A recent literature has begun to explore the macroeconomic implications of organizational capital and especially its ability to resolve discrepancies between existing models and data. For example, Gunn and Johri (2011) show that the presence of this kind of capital can help explain why firm equity values co-move with output and lead productivity in the context of expectation driven cycles. Johri (2009) shows that the presence of OC creates an incentive for price-setting firms to lower markups in times of monetary expansion which in turn leads to endogenous inertia in the price level and inflation. In an open-economy context, Johri and Lahiri (2008) show that the presence of OC can help explain the observed persistence of real exchange rate movements in the presence of monetary shocks. Despite these and other studies, potential implications of organizational capital remain largely unexplored.

This paper contributes to the OC literature by focussing on one such unexplored feature of OC—namely international investment flows—in the context of an international real business cycle (IRBC) model. It is well known (see for example the seminal work of Backus et al. (1992), BKK henceforth) that two-country models driven by productivity shocks have a hard time reproducing the observed positive cross-country co-movement in investment, even when the shocks are assumed to be positively correlated across countries. Indeed, the prototypical IRBC model will generate large negative cross-country correlations of investment. To see this, consider a positive shock to productivity in the home country that raises the relative return to capital in that country. The ensuing increase in investment in the home country is financed partially by domestic means as well as by resources which flow in from the foreign country. At the same time, investment is relatively less attractive in the foreign country so agents reduce foreign investment below steady-state levels and we end up with highly negative co-movement in investment between the two countries. Clearly investment in the real world does not flow across borders as freely as suggested by the model. While a number of reasons have been suggested in the IRBC literature to explain the positive co-movement of investment with mixed success,¹ here we wish to explore how the presence of OC may influence these flows. We elucidate this idea below.

In the real world, moving capital is expensive for many reasons. One reason that is not frequently modeled is the loss of OC that occurs in the process. Closing down factories or offices and moving them to another country involves permanent loss of some firm specific knowledge and skills embodied in workers and managers.² These losses would have a negative impact on productivity which can only be made up

¹See for example the work of Canova and Ubide (1998), Heathcote and Perri (2002), Kehoe and Perri (2002), Head (2002), Cook (2002), Pakko (2003), Corsetti et al. (2008)

²Or this knowledge may reside in the match between worker and capital or in a team. The dissolution of these matches or teams may lead to a loss of information and productivity.

slowly over time. Economic agents that realize this connection between investment decisions and future levels of productivity may be less willing to switch in and out of capital in response to temporary shocks.

While the canonical model tries to capture some of the costs of investment through quadratic costs to adjusting the capital stock, it does not take into account these potential productivity losses. The introduction of OC into the production technology is an attempt to try to take into account these additional considerations in the simple aggregate context of a one-good model. This paper also contributes to the IRBC literature by showing that these new considerations enable our OC model to deliver international co-movement in investment.

The specific mechanism by which this effect works is discussed next. Organizational capital is modeled following the learning-by-doing specification used in Cooper and Johri (2002) which is inspired by the early work of Arrow (1962) and especially Rosen (1972), in which agents accumulate OC as a by-product of past output. A crucial (and empirically important) feature of this specification is that OC created in the past makes a diminishing contribution to the creation of future levels of OC.³ As a result, reductions in current output lead to a reduction in future levels of OC which imply a fall in productivity. Since physical capital is used to produce output, a current reduction in investment leads to a future fall in capital and consequently a future fall in productivity. Realizing this dynamic linkage between investment decisions and future productivity levels, agents in the foreign country are loath to reduce investment in response to a home-country productivity shock.⁴

³See estimates provided in Cooper and Johri (2002) for sectoral manufacturing data, Benkard (2000) for a detailed investigation of the aircraft industry and Johri and Letendre (2007) for economy wide evidence.

⁴An alternative modeling strategy would have been to directly model the dynamic linkages between investment today and future productivity but we preferred to go with the relatively well established OC accumulation equation with similar implications and considerable empirical evidence

We now provide a brief discussion of the relevance of learning-by-doing and especially of our specification of OC. There is a large empirical literature documenting the pervasive influence of learning-by-doing in productive activities dating back a hundred years. Recent micro-economic studies include Benkard (2000), Thompson (2001), Thornton and Thompson (2001) and Clarke (2006). The learning-by-doing studies typically find that agents and organizations appear to become more productive as they gain experience at producing a particular product or service.

In order to deliver international co-movement in all major aggregate variables we adopt two other modifications of the one-good, two-country canonical model from the literature. The first is the assumption of incomplete asset markets of the kind discussed in Baxter and Crucini (1995). This asset structure is routinely assumed in the IRBC literature. The second is the use of preferences associated with the work of Greenwood et al. (1988), GHH henceforth.⁵ We show that this model, calibrated to US data, comes close to delivering all the key features of international co-movement discussed above. In particular the cross-country correlations of consumption, output, hours as well as investment are all positive. The role of GHH preferences is to make the cross-country correlation of hours positive as in Raffo (2008) while incomplete markets lowers the cross-country correlation of consumption. Sensitivity analysis shows our results are robust to reasonable variation in model parameters.

The paper is organized as follows. Section 2 presents our two-country model. Section 3 explains how we solve the model and select parameter values. Section 4 analyzes the dynamic properties of our model. Section 5 discusses the moments implied by our model and Section 6 offers some concluding remarks.

in its favor.

⁵GHH preferences are commonly used in the open-economy literature dating back to Devereux et al. (1992). See Letendre (2004), Letendre and Luo (2007), Raffo (2008) and Boileau and Normandin (2008a) for some recent examples.

2. Model

Our economy is composed of two countries labeled “the home country” and “the foreign country”. Each country is inhabited by a large number of infinitely lived identical agents. Both countries produce a homogeneous final good which may be used either for consumption or for investment. The final good can be traded freely across the two countries, but trade in financial assets is restricted to a simple non-contingent real bond. We denote all foreign country variables with an asterisk.

The representative agent in the home country seeks to maximize his expected lifetime utility given by:

$$\mathcal{U} = E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, N_t), \quad 1 > \beta > 0 \quad (1)$$

where the period utility function has the GHH form

$$U(C_t, n_t) = \frac{[C_t - \psi N_t^\nu]^{1-\sigma}}{1-\sigma}, \quad \psi > 0, \nu > 1, \sigma > 0 \quad (2)$$

where E_t denotes the mathematical expectation operator conditional on the agent’s time t information set, C_t denotes consumption, N_t denotes hours worked, β is a discount factor, σ is the coefficient of relative risk aversion, ν determines the Frisch labour supply elasticity and ψ determines the relative weight of consumption and leisure.

Output in the home country (Y) is produced using labour (N), physical capital (K), and organizational capital (H)

$$Y_t = A_t H_t^\varepsilon K_t^{1-\alpha-\varepsilon} N_t^\alpha, \quad 0 < \varepsilon, \alpha < 1, \quad (3)$$

where A_t is a stationary productivity shock. Since we are focusing on movements at the business cycle frequency we ignore technical progress of any form.

The technology differs from the standard neo-classical production function (used in the model without OC) because the agent carries a stock of organizational capital

which is an input in the production technology. Organizational capital refers to the information accumulated by the agent, through a learning process involving past production, regarding how best to organize his production activities and combine inputs. As a result, the higher the level of organizational capital, the more productive the agent. Note that there are diminishing returns to accumulating organizational capital, a feature often found in empirical studies of learning-by-doing.

There are at least two ways to think about what constitutes organizational capital. Some, like Rosen (1972), think of it as a firm specific capital good while others focus on specific knowledge embodied in the matches between workers and tasks or machines within the firm. While these differences are important, especially when trying to measure the payments associated with various inputs, they are not crucial to the issues at hand which involve the loss of these forms of knowledge as a result of disinvestment. As a result we do not distinguish between the two.

The exact specification of how learning-by-doing leads to productivity increases can be found in Cooper and Johri (2002) which draws on early work by Arrow (1962) and Rosen (1972). Learning is modeled through an accumulation equation for organizational capital which is closely related to the empirical learning-by-doing literature in which each cumulative unit of past production contributes equally to the creation of knowledge. Recent studies include Bahk and Gort (1993), Irwin and Klenow (1994), Jarmin (1994), Thompson (2001) and Thornton and Thompson (2001). Our specification differs from the typical one, in that the contribution of production in any period to the current level of organizational capital is decreasing over time. Following Cooper and Johri (2002), who provide evidence on this specification, we write the accumulation technology as

$$H_{t+1} = H_t^\gamma Y_t^\eta, \quad 0 < \gamma, \eta < 1 \quad (4)$$

where H_t denotes the stock of organizational capital available to the agent at time t .

H_0 denotes the initial endowment of organizational capital which must be positive.

This modification of the traditional specification of learning has a number of advantages. First, it allows for the sensible idea that production knowledge may become less and less relevant over time as new techniques of production and management, new product lines, new workers and new markets emerge. Second, it allows in a general way for the idea that some match specific knowledge may be lost to firms in the economy as workers leave or get reassigned to new tasks or teams within the firm. In addition, the knowledge accumulated through production experience will be a function of the current vintage of physical capital. The decision to replace physical capital will imply that the existing stock of organizational capital will be less relevant. Third, it allows for the existence of a steady state in which the stock of organizational capital is constant. In contrast, the traditional specification in the empirical learning-by-doing literature allows the stock of organizational capital to grow unboundedly. An alternative way to bound OC is to assume that productivity increases due to OC occur for a fixed number of periods. While this may be appropriate for any one task or worker within the economy, we think of the economy as a whole as an environment with an ever changing set of tasks, workers, teams, machines and information. In this context it may be better to model organizational capital as continually accumulating and depreciating.

The restriction $\gamma < 1$ is consistent with the empirical evidence supporting the hypothesis of depreciation of organizational capital often referred to as organizational forgetting. Argote et al. (1990) provide empirical evidence for this hypothesis of organizational forgetting associated with the construction of Liberty Ships during World War II. Similarly, Darr et al. (1995) provide evidence for this hypothesis for pizza franchises and Benkard (2000) provides evidence for organizational forgetting associated with the production of commercial aircraft. One difference between these studies and this paper is that the accumulation technology is log-linear rather than

linear. Clarke (2006) shows that the additional curvature in this log-linear technology produces similar predictions for aggregate variables in a closed economy context. We expect similar results to follow in the current context⁶.

The accumulation equation for the stock of physical capital in the home country is

$$K_{t+1} = (1 - \delta)K_t + I_t - \frac{\phi}{2} \left(\frac{I_t}{K_t} - \delta \right)^2 K_t, \quad 0 \leq \phi, \ 0 < \delta < 1 \quad (5)$$

where I_t denotes investment made in the home country and δ is the depreciation rate of physical capital. The accumulation equations for the stock of physical capital (5) and (7) include capital adjustment costs, which are governed by the parameter ϕ , to smooth investment movements. The adjustment costs function is set in such a way that the model with adjustment costs has the same steady state as the model without them.

For the foreign country, output is given by:

$$Y_t^* = A_t^* H_t^{*\varepsilon} K_t^{*1-\alpha-\varepsilon} N_t^{*\alpha} \quad (6)$$

and the capital accumulation equation is

$$K_{t+1}^* = (1 - \delta)K_t^* + I_t^* - \frac{\phi}{2} \left(\frac{I_t^*}{K_t^*} - \delta \right)^2 K_t^*. \quad (7)$$

Similarly organizational capital in the foreign country is accumulated via

$$H_{t+1}^* = H_t^{*\gamma} Y_t^{*\eta}. \quad (8)$$

The exogenous process for the productivity shocks is a bivariate autoregressive process (in logs):

$$\begin{bmatrix} \ln A_{t+1} \\ \ln A_{t+1}^* \end{bmatrix} = \begin{bmatrix} \rho & v^* \\ v & \rho^* \end{bmatrix} \begin{bmatrix} \ln A_t \\ \ln A_t^* \end{bmatrix} + \begin{bmatrix} \epsilon_{t+1} \\ \epsilon_{t+1}^* \end{bmatrix}, \quad E[\epsilon\epsilon^\top] = \sigma_\epsilon^2 \begin{bmatrix} 1 & \tau \\ \tau & 1 \end{bmatrix} \quad (9)$$

⁶Another seemingly crucial feature of our model is that organizational capital is accumulated as a by-product of production. This ignores the considerable intentional investments made by firms in raising productivity. Hou and Johri (2010) show that allowing for intentional investments in organizational capital result in only small differences from the Cooper and Johri (2002) model.

where ρ and ρ^* measure the persistence of domestic and foreign productivity shocks, v and v^* measure the degree of spillovers across countries, σ_ϵ^2 denotes the variance of innovation ϵ and τ denotes the cross-country correlation of innovations.

The financial markets in our world economy are incomplete. More specifically, only one-period risk-free real bonds can be traded. These bonds are traded at price $P_t = (1 + r_{t+1})^{-1}$, where r_{t+1} is the domestic real return on bonds purchased in period t . That is, r_{t+1} is the interest rate linking periods t and $t + 1$. We denote the quantity of discount bonds purchased by residents of the home country in period t by B_{t+1} (each paying one unit of consumption in period $t + 1$). The budget constraint for the representative agent in the home country is

$$C_t + I_t + P_t B_{t+1} = Y_t + B_t. \quad (10)$$

The budget constraint for the foreign country agent is

$$C_t^* + I_t^* + P_t^* B_{t+1}^* = Y_t^* + B_t^*. \quad (11)$$

We assume that bonds are in zero net supply, so bond market clearing requires

$$B_t + B_t^* = 0. \quad (12)$$

Following Devereux and Smith (2007) we assume there are some frictions in the bond market that create an interest rate differential across countries. Formally we assume

$$1 + r_{t+1} = (1 + r_{t+1}^*) e^{-\chi[B_{t+1} - \bar{b}]}, \quad \chi > 0 \quad (13)$$

where r_t^* is the foreign real interest rate and \bar{b} denotes bond holdings of the home country in steady state. The “premium” $e^{-\chi[B_{t+1} - \bar{b}]}$ appearing in (13) implies that the further in debt the domestic country gets (the more negative B becomes) the higher the interest rate at home compared to the foreign country. The bond price version of equation (13) is

$$P_t^* = P_t e^{-\chi[B_{t+1} - \bar{b}]}.$$

Technically, we need a mechanism to deal with the existence of a unit root in bond accumulation in the incomplete markets economy and our “risk premium” is one way to make the model stationary (see Boileau and Normandin (2008b) for more on this issue).

3. Model Solution and Parameter Values

An approximate linear solution to our model is obtained using the method outlined in King et al. (2002). The first-order conditions and details about how we solve the model (and a special case of it without OC) can be found in the appendix of Johri et al. (2010). The KPR method requires us to assign values to the model’s parameters. Except for the values associated with OC most of the parameter values used in our work are commonly found in the business cycle and international macro literature. We now explain how we assign values to the parameters in our international business cycle model with OC (Table 1 provides a summary of our parameter values).

The reference period is a quarter. Following the IRBC literature we set the coefficient of relative risk aversion, σ , to 2. We let ψ adjust so that the fraction of time spent working in steady state is equal to 0.3. The remaining preference parameter ν is set to 3 so that the Frisch labour supply elasticity has a value of 0.5 which is near the middle of the range of micro estimates. We set the discount factor β to 0.993 a common value in the RBC literature (see Burnside and Eichenbaum (1996) among others).

The United States net foreign asset position has dramatically changed since the early 1980s. From the 1950s to the early 1980s, the position (as a percentage of output) was around 10% (see for example Masson et al 1994). It has since plunged to around negative 20% (see for example Gourinchas and Rey (2007)). The average over the

period 1975-2005 is close to zero (-0.03). Accordingly, we set $\bar{b} = 0$ which implies zero net foreign asset holding in steady state.

An estimate of χ can be found in Lane and Milesi-Ferretti (2001): $\chi = 0.001$.

The capital adjustment cost parameter ϕ is set to produce a realistic investment volatility relative to the volatility of output. While the exact number for this relative volatility varies slightly from one paper to the next, it is normally around 3 for US data detrended with the Hodrick-Prescott or band-pass filters. For example, BKK (1995) report a relative investment volatility of 3.27, Baxter and Farr (2005) report 2.98, and Chari et al. (2002) report 2.78. Accordingly, we set ϕ so that the model produces a relative standard deviation of investment of 3.

For the technology parameters, we use the values $\alpha = 0.55$, $\varepsilon = 0.24$, $\delta = 0.02$, $\gamma = 0.95$, and $\eta = 1 - \gamma = 0.05$ estimated by Johri and Letendre (2007) using aggregate US data. These values imply a capital-output ratio of 9.8 and a labour share of 0.7. Also, the value $\varepsilon = 0.24$ implies an eighteen percent learning rate which is fairly conservative.

Finally we discuss the parameters related to the technology shocks. As is commonly done in the literature the variance of the innovations σ_ϵ^2 is adjusted so that each model (one with OC and one without) matches the standard deviation of output in the data. Again, this value varies across papers for US data. For example, BKK (1995) report a value of 1.92, Baxter and Farr (2005) report 1.69, and Chari et al. (2002) report 1.82. The latter number is in the middle of the pack so we set σ_ϵ^2 to match it.

The presence of OC in production function (3) implies that the Solow residual takes a different form than in other models (*e.g.* BKK) where raw labour and physical capital are the only inputs. In those other models the Solow residual is exactly equal to the technology shock while in our model with OC the Solow residual is

an endogenous variable which equals (in logarithms) $\ln A + \varepsilon \ln H$. We recognize that simply borrowing parameter values from previous empirical work relying on a standard production function (where labour and capital are the only inputs) would ignore that theoretical difference in the Solow residual's composition. Accordingly, we set the parameters of our technology shocks in such a way that the model with a more traditional production function (no OC) and our model with OC imply the very same persistence and cross-country correlations in the Solow residuals. The rest of this section explains how we accomplish this.

International spillovers are not estimated precisely (see for example BKK (1992)) so we follow Baxter and Crucini (1995), Baxter and Farr (2005) and Kehoe and Perri (2002) (to name a few) and set $v = v^* = 0$ in both models.

We follow Kollmann (1996), Kehoe and Perri (2002) and others and set the persistence of the (non-HP filtered) Solow residual to 0.95. Recall that in those papers Solow residual and technology shock are identical. This is not the case in our model. Since OC generates some additional persistence in the HP filtered Solow residual we actually use a slightly lower ρ in the OC model ($\rho = 0.945$) than in the no-OC model ($\rho = 0.95$) so that the autocorrelation of the HP filtered Solow residual is the same (0.68) in both models.

For the cross-country correlation of the Solow residual we use a recent estimate (0.323) calculated by Boileau and Normandin (2008b). Their estimate is slightly larger than the one (0.258) found by Backus et al (1992). This is understandable since BKK allowed the process for the Solow residual to have non-zero international spillovers. Given that our process is assumed to have zero spillovers we think that Boileau and Normandin's estimate, which was computed imposing zero spillovers, is a more appropriate number. Accordingly we set $corr(\epsilon, \epsilon^*)$ in such a way that the cross-country correlation of the Solow residual is 0.32. Note that in our simulations, OC

does not impact significantly on the cross-country correlation of the HP filtered Solow residual. For that reason we use $corr(\epsilon, \epsilon^*) = 0.323$ in both of our models.

4. Dynamics of the model

In this section we discuss the economics of our model in the context of impulse responses to technology shocks which can be found in Figures 1 and 2. To calculate impulse response functions (IRFs) we simulate the model while feeding it the following matrix of innovations

$$\begin{bmatrix} \epsilon_t \\ \epsilon_t^* \end{bmatrix}_{t=1}^{\infty} = \begin{bmatrix} 0.01 & 0 & 0 & 0 & \dots \\ 0.01 \, corr(\epsilon, \epsilon^*) & 0 & 0 & 0 & \dots \end{bmatrix}. \quad (14)$$

That is, the home country experiences a one percent positive shock and the foreign country simultaneously experiences a shock of size $0.01 \times corr(\epsilon, \epsilon^*)$. We look at the responses of both the models with and without OC for two separate cases, one where $corr(\epsilon, \epsilon^*) = 0.323$ and another where $corr(\epsilon, \epsilon^*) = 0$.

4.1 Investment Dynamics

Figure 1 plots the response of investment for both countries in the calibrated versions of our model (labeled I OC and I^* OC) and its no-OC version (labeled I and I^*). The impact of organizational capital is clearly visible in the figure, especially for the dynamics of investment in the foreign country. While I^* falls below steady state on impact, I^* OC rises and stays above steady state for a number of periods. Recall that the path of foreign country investment in this figure is jointly determined by the exogenous movement in technology, A^* (due to the presence of correlated shocks) and the endogenous response of the foreign country agent to the home country shock. In

order to isolate the impact of organizational capital on the dynamics of the model, we wish to switch off the former effect. As a result, in Figure 2, we study the case of uncorrelated shocks where A^* remains at steady state levels throughout the exercise. We also impose the same value of ϕ (namely $\phi = 2.76$) on both models so that this is no longer a source of variation between the responses of the two models.

Figure 2 emphasizes the different responses of the foreign agent to the domestic shock across the two models. In the model without organizational capital, investment falls in the foreign country and stays below steady state for roughly ten quarters. The presence of organizational capital cuts the negative response of the foreign agent by about half on impact and shortens the time spent below steady state to about five quarters. Comparatively speaking, the response of the domestic agent is similar in the two models, though there is some evidence of magnification in the OC model. In order to analyze these differential responses in Figure 2, we will study the two models in turn, starting with the no-OC model. We will end the discussion with a brief comment on the additional impact of the exogenous shocks in Figure 1.

4.1.1 Model without Organizational Capital

In order to explain why investment behaves differently in the two countries we look at the capital first-order conditions abstracting from adjustment costs.

$$1 = E_t \beta \frac{\lambda_{1t+1}}{\lambda_{1t}} \left\{ \frac{(1-\alpha)A_{t+1}N_{t+1}^\alpha}{[(1-\delta)K_t + I_t]^\alpha} + 1 - \delta \right\} \quad (15)$$

$$1 = E_t \beta \frac{\lambda_{1t+1}^*}{\lambda_{1t}^*} \left\{ \frac{(1-\alpha)A_{t+1}^*N_{t+1}^{*\alpha}}{[(1-\delta)K_t^* + I_t^*]^\alpha} + 1 - \delta \right\} \quad (16)$$

A glance at (15) and (16) reveals that the response of investment is governed by two factors which we discuss in turn. The first factor is the expression within braces which captures the return to capital accumulation. The second factor is the marginal rate of substitution between consumption in periods t and $t+1$ given by $MRS \equiv \beta \lambda_{1t+1} / \lambda_{1t}$.

In the impact period of the shock, since capital is predetermined, the return on capital for a given level of investment is governed mainly by A_{t+1} directly and indirectly through its effect on N_{t+1} . As we will discuss below, hours will rise in the home country so that the return to accumulating capital rises. On its own, this would cause the home country agent to increase investment. This desire to invest is somewhat dampened by a small fall in the MRS as consumption rises slowly due to the desire to smooth consumption. To satisfy the Euler equation (15), investment must increase in the home country and stay above steady state until the persistent effects on the productivity of capital slowly wear off.

The analysis of the response of the foreign agent uses the same elements as above but is simplified by the absence of any exogenous movement in productivity since we are studying the uncorrelated shock case in Figure 2. Anticipating the analysis of the next section, since the response of N^* (which is governed by A^* and K^*) is zero on impact and extremely small in the period after the shock, there is hardly any movement in the return to capital. As a result, the drop in I^* can be understood mostly by the movement in MRS^* .

Why does MRS^* fall when productivity rises in the home country? Recall that the two countries are linked together by trade in bonds. The Euler equation for bonds in the foreign country implies

$$P_t^* = E_t \beta \frac{\lambda_{1t+1}^*}{\lambda_{1t}^*} \quad (17)$$

The persistent positive shock in the home country creates a desire for an increase in investment and consumption there. In a closed economy, either the desire for increased consumption must be tempered or leisure sacrificed in order to satisfy the desire for more capital. Both of these responses reduce utility and dampen the increase in investment. In an open economy, however, there exists an alternative avenue to finance investment: acquiring resources from the other country. In our model environment, the home country can finance some of its investment through international

borrowing by selling bonds to the foreign country. For the bond market to clear, the additional supply of bonds must result in a fall in their price below steady state.

The Euler equation (17) implies that the fall in P^* must be accompanied by a fall in MRS^* . In other words the return to bonds must rise above its steady state value in order to induce the foreign agent to postpone his consumption. This allocative signal also induces the observed fall in investment in the foreign country.

When shocks are correlated across countries, the price of bonds must fall even more because the small shock experienced by the foreign country raises the return to investment and, everything else equal, makes the foreign agent also interested in borrowing to invest. Since the home shock is much bigger, and the home country's desire to borrow much greater, the bond price must fall even more than in the zero-correlation scenario to convince the foreign country to lend to the home country.

4.1.2 Model with Organizational Capital

We now turn to the response of investment in our model with OC in Figure 2 which will be followed by a short discussion of the case depicted in Figure 1 with correlated shocks. The focus of our discussion will be the differential response of investment in the foreign country relative to the model without OC discussed above. In order to understand why the drop in investment in the foreign country is so much smaller than in the no-OC model we turn to the foreign country Euler equation abstracting once more from adjustment costs

$$1 = E_t \beta \left\{ \frac{\lambda_{1t+1}^*}{\lambda_{1t}^*} \left(\frac{(1 - \alpha - \varepsilon) A_{t+1}^* N_{t+1}^{*\alpha} H_{t+1}^{*\varepsilon}}{[(1 - \delta) K_t^* + I_t^*]^{\alpha + \varepsilon}} + 1 - \delta \right) + \frac{\lambda_{3t+1}^*}{\lambda_{1t}^*} \frac{(1 - \alpha - \varepsilon) \eta H_{t+2}^*}{[(1 - \delta) K_t^* + I_t^*]} \right\} \quad (18)$$

Given the similarities of the two models, the impact of bond prices and the marginal product of capital on the behavior of investment is relatively similar and not sur-

prising. The foreign agent is induced to postpone consumption, buy home country bonds and reduce investment. This effect is mitigated by the presence of a new term appearing in the capital Euler equation. This term captures the value of time $t + 2$ organizational capital that is induced by the extra output created by having an additional unit of physical capital in $t + 1$ and reflects the fact that agents internalize this link between investment in period t and the amount of organizational capital available in $t + 2$. Should we expect this effect to moderate the desire of the foreign agent to reduce I_t^* ? The answer lies in the signal sent by the relative price (value) of organizational capital to the consumption good. This price is captured in the ratio of Lagrange multipliers $\lambda_{3t+1}^*/\lambda_{1t}^*$ in (18) which represents the value of an additional unit of H_{t+2}^* in terms of current consumption. This price will rise as future quantities of organizational capital become relatively scarce as can be seen in Figure 3. On its own, this rise in the relative price of future organizational capital induces the agent to try to accumulate more of the scarce factor. Overall, it acts as a countervailing force to the strong incentives coming from the home country via the fall in bond prices. This results in a smaller drop in investment on impact as well as a shorter duration of time spent below steady state investment levels.

Turning from Figure 2 to Figure 1, the main difference is that the foreign country now also receives a small shock which raises its marginal product of capital. The foreign agent now has an additional incentive to increase investment which is sufficient to make its investment response positive.

4.2 Hours Dynamics

Since the effect of GHH preferences on the behavior of hours is relatively well understood, we only provide a short discussion without any figures of what to expect from the two models. To understand the role of GHH preferences it is useful to compare

the first-order condition for hours in our no-OC model and a variant of it where the periodic utility function takes the iso-elastic form

$$U(C_t, n_t) = \frac{[C_t^\psi (1 - N_t)^{1-\psi}]^{1-\sigma}}{1 - \sigma}, \quad 1 > \psi > 0, \sigma > 0 \quad (19)$$

instead of the GHH form in (2).

The hours first-order condition of the no-OC model with preferences (19) is given below. It equates the marginal disutility of working an extra hour with the marginal utility gain from the extra output produced. An equivalent condition for the foreign country is suppressed.

$$\frac{1 - \psi}{1 - N_t} = \alpha \frac{\psi}{C_t} \frac{Y_t}{N_t} \quad (20)$$

Recall that a weakly correlated productivity shock raises the marginal product of labour in both countries. On it's own, this encourages both countries to raise hours above steady state. With standard preferences the increase in consumption fueled by the wealth effect, however, tends to dampen the desire to increase hours. In the home country the former dominates the latter but in the foreign country the relatively weak productivity shock is overshadowed by the wealth effect resulting in hours falling quickly.

With GHH preferences, the wealth effect is eliminated. As a result only the substitution effect operates on hours as can be seen from the hours first-order condition.

$$\psi \nu N_t^{\nu-1} = \alpha \frac{Y_t}{N_t} \quad (21)$$

This suggests that hours and labour productivity will move together in both countries. Linearizing the above condition and the production function yields $(\nu - \alpha)\hat{N}_t = \hat{A}_t + (1 - \alpha)\hat{K}_t$ where a “hat” denotes a variable in percent deviation from its steady state (*e.g.* $\hat{N}_t \equiv (N_t - \bar{N})/\bar{N}$). Given the typical smoothness in the response of the stock of physical capital, the linearized condition shows that hours are largely driven by technology shocks (entirely in the first period). Therefore, the positive

comovement in hours across countries is a reflection of the positive cross-country correlation of shocks.

The OC model introduces additional considerations in the decision regarding hours worked similar to investment. These considerations turn out not to be very important from a quantitative stand point, therefore we do not discuss them here. Additional details can be found in Johri et al. (2010) while detailed impulse responses are available from the authors. Based on the responses of the models with and without OC, it would appear that GHH preferences mainly influence the dynamics of hours while OC influences the dynamics of investment. We now turn to a calculation of second moments to see if these changes are sufficient to deliver positive international correlations in all key aggregate variables.

5. Moments

In this section we discuss the usual second moments for our model and the variant without OC which are compiled in Table 2.

The first column of numbers in Table 2 corresponds to the data⁷ while the second column corresponds to our model.⁸ In the first column, we see that the cross-country correlation of consumption, hours, investment and output are all positive. In their comprehensive study of cross-country correlations Ambler et al (2004) conclude that “A remarkable common feature emerges: these correlations are mostly positive, not very high and of a similar order of magnitude.” As the second column of numbers

⁷Numbers in the “Data” column are ranges constructed using the statistics reported by BKK (1995), Chari et al. (2002), and Baxter and Farr (2005).

⁸Artificial data are in percent deviations from steady state (except for the trade balance) and have been HP filtered. The moments reported are averages over 1000 replications. Each replication is 100 quarters long.

shows, our model accords with their conclusion. Focusing specifically on the international correlation of investment, we see that the model delivers a value of 0.15 which is somewhat lower than the range seen in the data. As we show later in Figure 4, lowering γ (holding η constant) has a dramatic influence on this correlation. If we lower it from the calibrated value of 0.95 to 0.8, the international correlation jumps up to 0.3 which is within the range of values found in the data. In order to understand why this occurs, recall that γ governs the rate at which organizational capital is lost over time. The higher the value of γ , the longer it lasts. If γ is very close to unity, then temporary reductions in aggregate output below steady state levels have a very small future affect on the level of organizational capital since most of the old knowledge is still available a few years later. As a result, the foreign country is not very reluctant to lower investment when the home country gets a positive productivity shocks. As γ falls, the reluctance to lower output and investment increases because the “depreciation” of organizational capital increases, as does the need to continually replace it. As a result, temporary reductions in output and investment end up hurting the future productivity of the economy much more which then leads to higher international investment correlations.

In order to highlight the impact of OC we report the results of the no-OC model in the third column of numbers. We set ϕ to ensure the relative volatility of investment in the no-OC model is three just like in the OC model.⁹ As explained in Section 3 we need to set ρ marginally higher (0.95) in the no-OC model to ensure the autocorrelation of the Solow residual is the same in both models. Finally we raise the share of physical

⁹A feature of the IRBC model (with or without organizational capital) is the existence of a tradeoff between investment volatility and cross-country correlation of investment. That is, even the canonical model could produce a positive cross-country correlation of investment if capital adjustment costs were set sufficiently high. When such high adjustment costs are assumed, investment volatility is unrealistically low. We do not allow this tradeoff to operate by forcing both the OC and no-OC models to produce a relative volatility of investment consistent with the data. In the no-OC model $\phi = 1.73$.

capital in the production technology in order to maintain constant returns to scale once organizational capital is removed.

Removing OC from the model has a big impact on the investment correlation which turns sharply negative as suggested by the impulse responses discussed in section 4. Other international correlations also fall a little but remain positive. There is no dramatic change in the relative standard deviation of consumption and hours. Since OC affects investment dynamics, we also report the first-order autocorrelation of investment which increases only slightly. Both models are consistent with the fact that output is negatively correlated with the trade balance-output ratio and they both struggle at matching the volatility of the latter. Correlations of consumption, hours and investment with output (not reported) are all large and positive in both models.

The last column of Table 2 reports numbers for the OC model with complete markets.¹⁰ Going from the bond economy to complete markets leaves most of the international correlations near their old values. As expected, the one significant change is that the international correlation of consumption increases from 0.43 to 0.79, taking it out of the range of values found in the data. When asset markets are complete, countries can share risk more efficiently which makes consumption levels more similar across countries.

This section provides some sensitivity analysis with a focus on the international correlation of investment implied by the model. We focus our discussions on three key parameters governing the cross-country correlation of shocks, the Frisch elasticity of labor supply and the rate at which organizational capital depreciates.¹¹

¹⁰We thank a referee for suggesting this exercise.

¹¹Varying other parameters within empirically reasonable values appears to have less of an effect on cross-country investment correlations. Lowering β to 0.984 or raising σ to 3 increase the comovement of investment to 0.17 and 0.16 respectively. Varying the relative weight of the two capital

The international correlation of productivity shocks is an important driver of all the international correlations. The first panel of Figure 4 reports the correlations of consumption and of output for the OC model while the second panel reports investment correlations for both the OC and no-OC models as the correlation of productivity shocks is varied from zero to 0.4. In all panels we keep the other parameters constant. The correlation of output rises from zero to 0.39 in a roughly linear manner while the correlation of consumption is always above that of output by roughly the same amount. We do not report the correlation of hours as it pretty much follows that of output in the presence of GHH preferences. The second panel of Figure 4 shows that the investment correlation is also closely related to the correlation of productivity shocks. When shocks are uncorrelated, the no-OC model predicts that investment will be highly negatively correlated (-0.6) for the reasons discussed previously. As the shocks become progressively more correlated, investment correlations increase to -0.3. The OC model displays a higher level of correlation even in the absence of any correlation in shocks. The correlations for the OC model range from -0.18 to 0.23 as shocks become more correlated. The finding that international correlations rise with the correlations of shocks is intuitively clear. As shocks become more and more similar, the two countries become less and less different. In the limit case of perfectly correlated shocks, both countries behave exactly the same and all international correlations are unity

The third panel of Figure 4 explores another important parameter, the Frisch elasticity of labour supply governed by ν . As the elasticity increases from $1/3$ to 1.25, the international correlation of investment falls from -0.3 to -0.6 for the no-OC model. Our baseline OC model does better at generating comovement in investment. For

stocks in the production technology has a somewhat larger impact. As ϵ falls in favor of the share of physical capital, we get closer to the no-OC model. This leads to a lower correlation of investment which falls from 0.15 to 0.06 as ϵ goes down to 0.2. In all exercises, the international correlation of investment compares favorably to -0.38 in the no-OC model.

the same elasticities, the correlations range from 0.19 to -0.02. The third line in the figure, explores the role of γ in the model. Lowering the level of γ from 0.95 to 0.8, raises the investment correlations for all elasticity levels, giving rise to positive correlations even at the higher end.

We conclude from our sensitivity exercises that the ability of OC to improve the international investment correlation is quite robust.

6. Concluding Remarks

This paper contributes to the expanding organizational capital literature by documenting the effect of organizational capital on international investment flows in the context of an international real business cycle model. To the best of our knowledge no one has done this before.

This paper also contributes to the IRBC literature by showing that the addition of organizational capital to an IRBC model modifies the dynamics of investment in such a way that our model delivers a positive international correlation of investment. The canonical IRBC model and several of its extensions produce a negative correlation (see Baxter and Farr (2005) for a recent attempt at producing a positive international correlation of investment, and the references therein).

In a nutshell, organizational capital dampens the foreign country's willingness to reduce investment when the home country experiences a positive productivity shock. Therefore, when the shocks are slightly correlated across countries the model succeeds at producing a positive response of investment in both countries. Despite this success there remain some issues in reproducing the international correlations seen in the data. Our baseline parameterization delivers correlations that are somewhat smaller

than those in the data. Moreover, the international correlation of consumption is slightly higher than that of output which is at odds with the US data¹². These issues can be addressed in the future by incorporating into the model some of the other economic mechanisms explored in the two-country model literature that have been shown to deliver higher output correlations and lower consumption correlations. For example, Boileau (2002) introduces trade in capital goods along with investment specific technical change, Cook (2002) introduces entry and exit in imperfectly competitive markets, and Baxter and Farr (2002) explores the role of variable capital utilization. All these papers find that these mechanisms help in matching model driven moments to data moments.

Acknowledgements

Johri thanks the Social Sciences and Humanities Research Council of Canada for financial support. Luo thanks the financial support by Leading Academic Discipline Program, 211 Project for Shanghai University of Finance and Economics (the 3rd phase). Helpful comments were provided by two anonymous reviewers and seminar participants at Brock University, Wilfrid Laurier University, University of Guelph, at the meeting of the Canadian Economic Association 2007, Midwest Macro 2008, North American Summer Meetings of the Econometric Society 2009, and Small Open Economy in a Globalized World 2008. We thank Keqiang Hou and Christopher Gunn for research assistance.

¹²Ambler et al (2004), point out that other nations do not necessarily exhibit the same pattern as the US. In roughly 30 percent of all possible bilateral pairs, consumption correlations are indeed higher than output correlations.

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Table 1: Parameter Values

Preferences: $\beta = 0.993$, $\sigma = 2$, $\nu = 3$, $\psi = 6.174$.

Technology: $\alpha = 0.55$, $\varepsilon = 0.24$.

Capital accumulation: $\phi = 2.76$, $\delta = 0.02$, $\gamma = 0.95$, $\eta = 0.05$.

Productivity shocks: $\rho = \rho^* = 0.945$, $v = v^* = 0$, $\sigma_\varepsilon^2 = 0.012^2$, $\tau = 0.323$.

Others: $\bar{b} = 0$, $\chi = 0.001$

Table 2 : Moments

Moment	Data	OC	no-OC	OC-CM
<i>Standard Deviations (SD)</i>				
$SD(Y)^a$	1.69–1.92	1.82	1.82	1.82
$SD(C)/SD(Y)$	0.75–0.83	0.54	0.48	0.48
$SD(N)/SD(Y)$	0.61–1	0.31	0.33	0.31
$SD(I)/SD(Y)^a$	2.78–3.27	3	3	3
<i>Cross-Country Correlations</i>				
Y	0.29–0.66	0.31	0.29	0.31
C	0.12–0.51	0.43	0.27	0.79
N	0.33–0.43	0.32	0.29	0.32
I	0.25–0.53	0.15	-0.38	0.16
<i>Others</i>				
$autocorr(I)$	0.91–0.92	0.67	0.65	0.67
$corr(TB/Y, Y)$	-0.37– -0.31	-0.16	-0.46	0.39
$SD(TB/Y)$	0.39–0.62	0.15	0.87	0.24

Notes: ^a denotes a moment that is targeted in the calibration (see Section 3 of the paper). Column *OC* (*no-OC*) reports moments of the model with (without) organizational capital. Column *OC-CM* reports moments of the model with organizational capital and complete financial markets. Numbers in the “Data” column are ranges constructed using the statistics reported by BKK (1995), Chari, Kehoe and McGrattan (2002), and Baxter and Farr (2005). Except for the trade balance, all data are in logs and have been detrended using the HP filter (BKK and CKM) or a band-pass filter (BF).

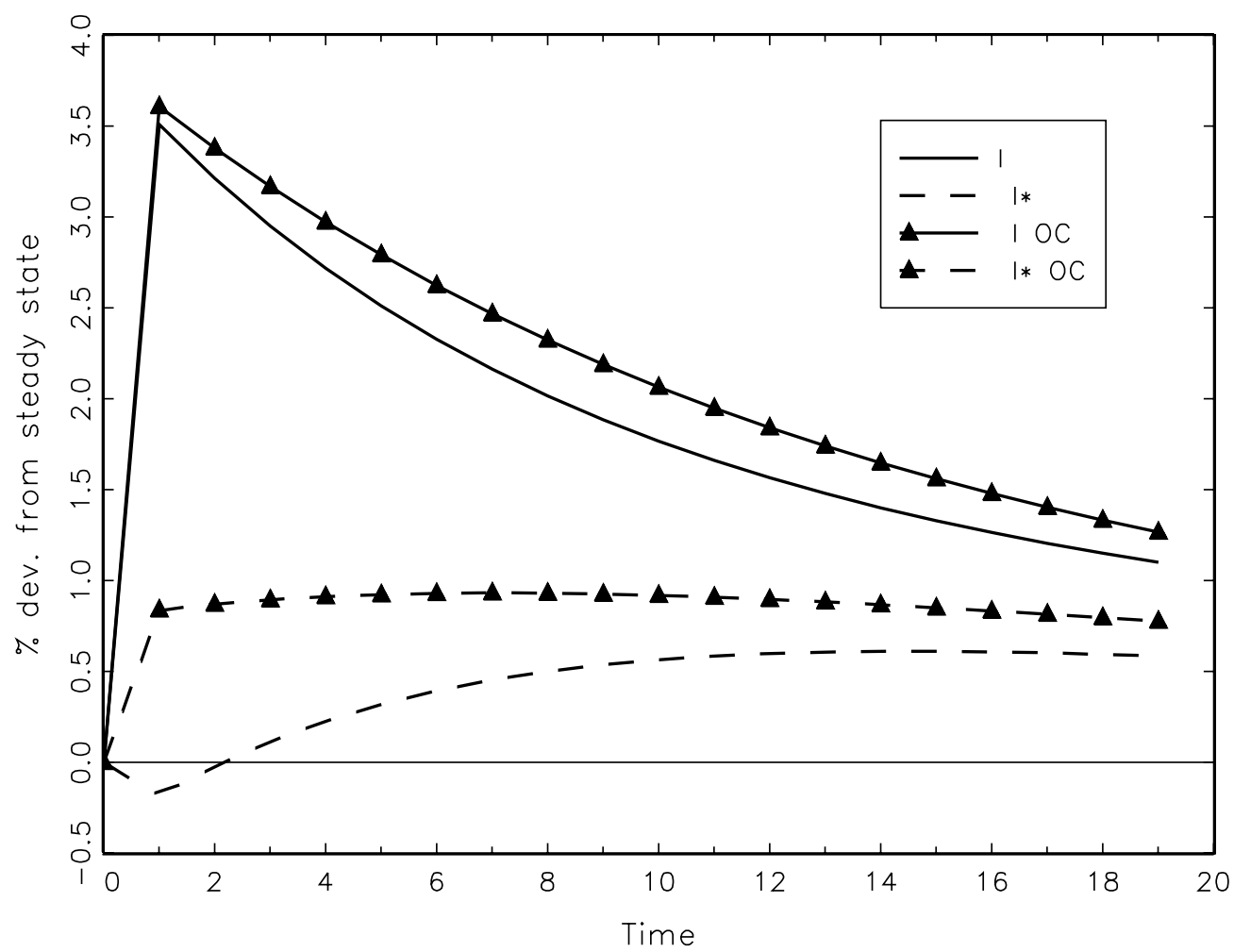


Figure 1

Investment Response to Correlated Shocks

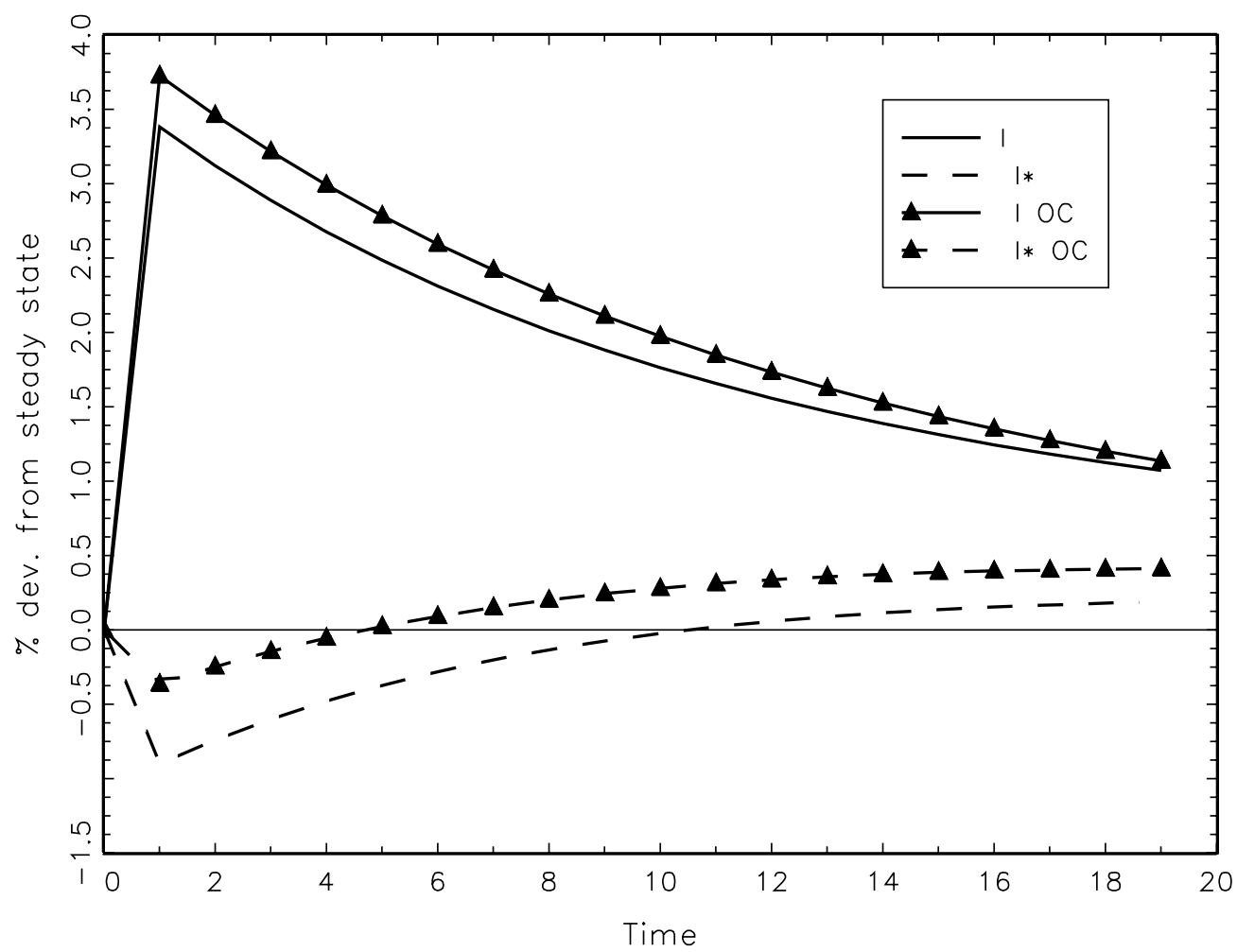


Figure 2

Investment Response. Uncorrelated Shocks (Same ϕ for both Models)

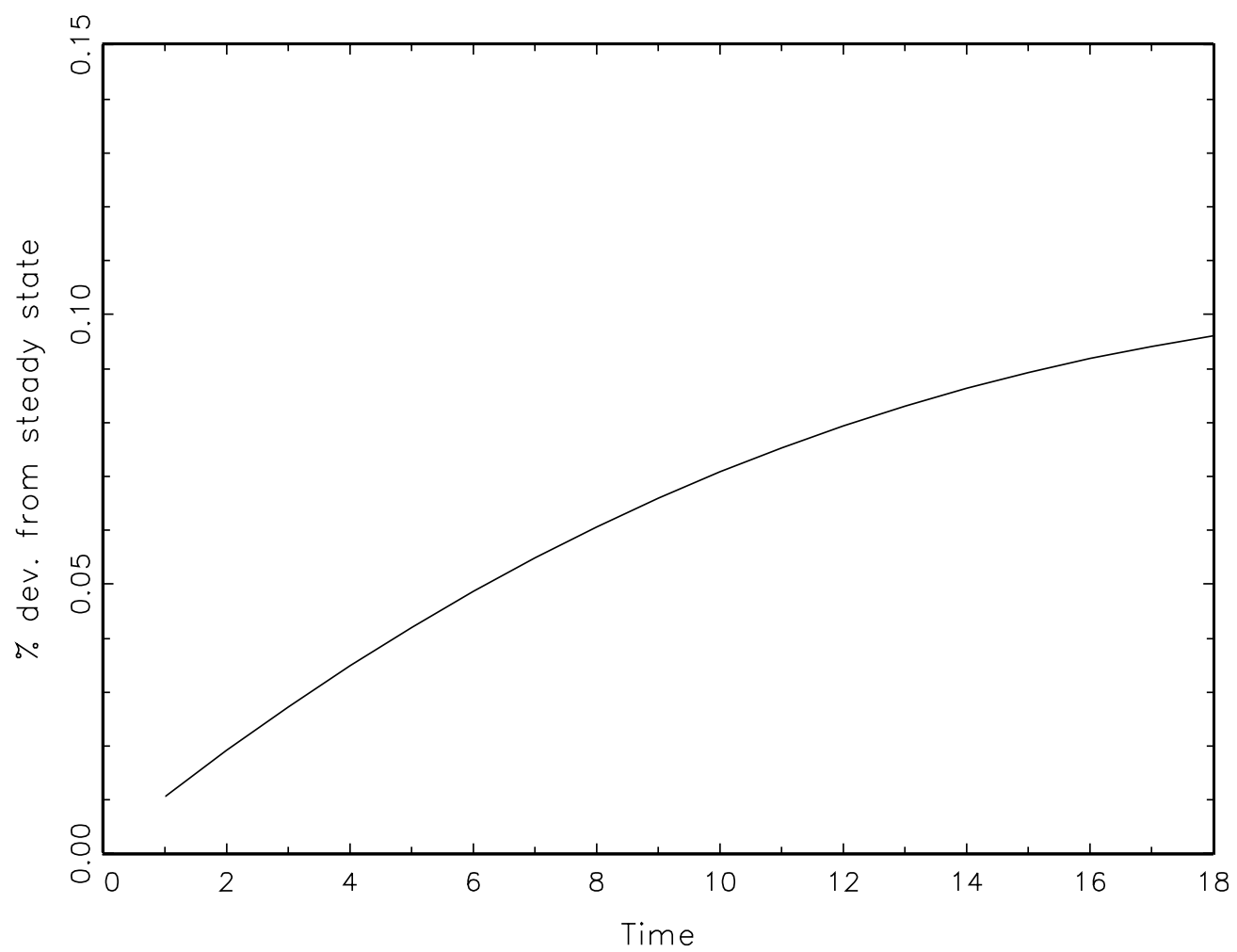


Figure 3

Value of Future OC in Terms of Current Consumption

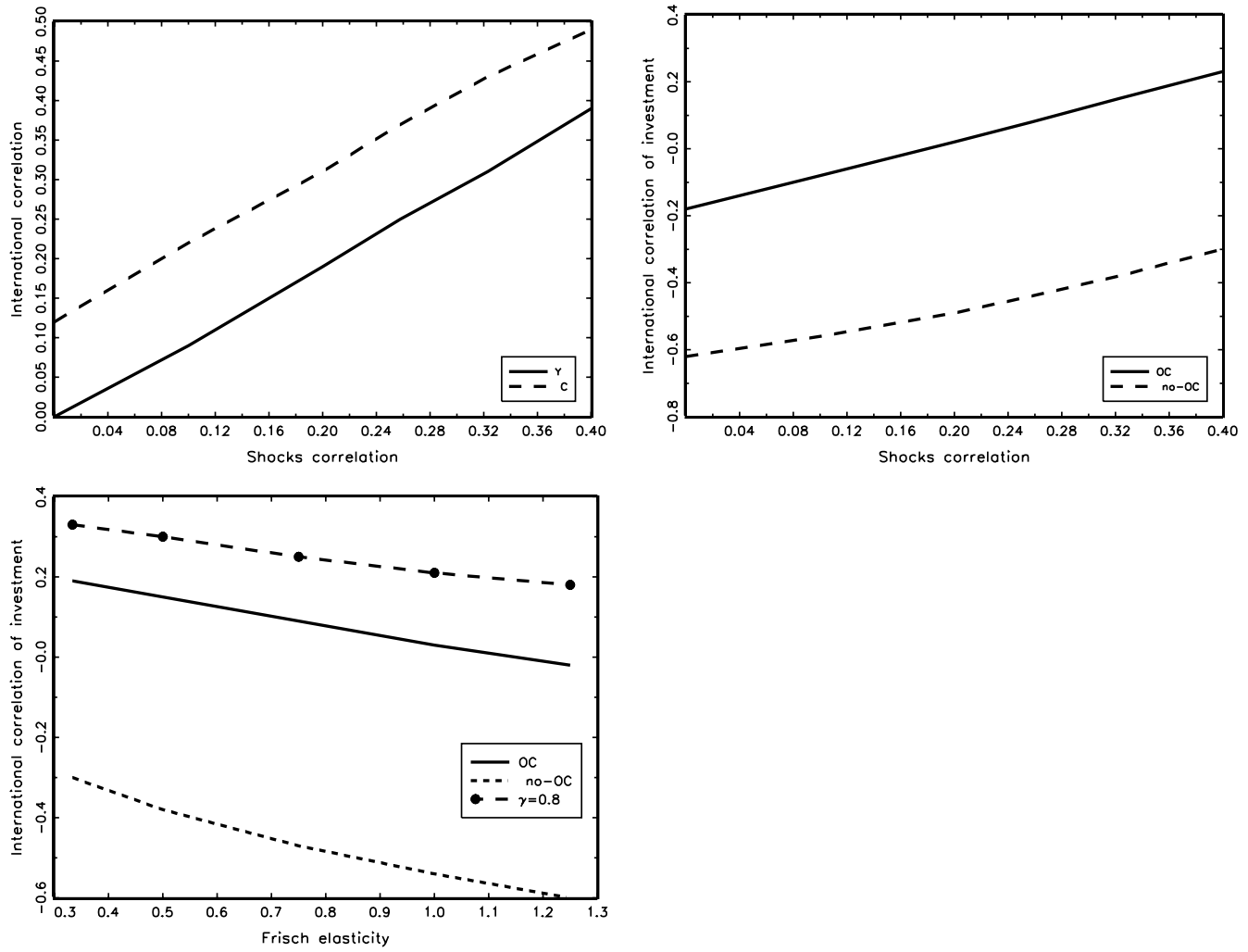


Figure 4

Sensitivity Analysis